STUDY OF VARIOUS METHODS FOR THE REMOVAL OF ARSENIC CONTAMINATION IN GROUNDWATER

A Thesis submitted in partial fulfilment

for the requirement of the degree of

Bachelor of Technology in Civil Engineering

By

Aman Gautam

Department of Civil Engineering

National Institute of Technology, Rourkela

2014

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Under the supervision of

Prof. Kakoli K. Paul

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2014

CERTIFICATE

National Institute of Technology
Rourkela

This is to certify that the project entitled "STUDY OF VARIOUS METHODS FOR THE REMOVAL OF ARSENIC CONTAMINATION IN GROUNDWATER" submitted by Aman Gautam, Roll No. 11CE0457 in partial fulfilment of the requirement of the award of Bachelor of Technology degree in Civil Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university /Institute for the award of any Degree or Diploma.

Date: (Prof. KAKOLI K. PAUL)

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ABSTRACT

High concentrations of arsenic in groundwater have caused great health problems all across the world. In the present field of study, different methodologies of arsenic removal has been studied by using some hybrid materials such as Activated Charcoal (charcoal) in addition with Ferric Chloride, Coarse Calcite along with Ferric Sulphate(hydrous) and Portland Cement. These hybrid materials were prepared by sol-gel and co-precipitation method. Sodium arsenite and sodium arsenate standard solutions were used for preparing standard solutions of arsenic of required concentration. AAnalyst200 Atomic Absorbtion Spectrometer (AAS) was used for measuring the residual concentration of arsenic after the remotion techniques and parameters like pH, reaction temperature, period of time and concentration of the adsorbate/coagulant were varied to study their effects on the elimination of arsenic. These hybrid or conflated materials showed assuring results in removing arsenic from the prepared samples.

The maximum efficiency showed by Activated Carbon (AC) was 96.22 percent at neutral pH, concentration: 8g/L and forced hydrolysis time period: 6 hours towards 0.05ppm As solution.

The maximum efficiency showed by HPPC was 95.84 percent for pH equals to 5.1, concentration: 15g/L and adsorption period- 8hours on 0.2 ppm As solution.

Coarse Calcite was the most efficient hybrid material which showed an efficiency of 99 percent at a concentration of 5g/L, pH: 4.0 and reaction time of 30 minutes against 5ppm As solution.

For the same concentration of 0.2ppm, these hybrid materials were analysed and it was found that both HPPC and Coarse Calcite have nearly same efficiency of 93 percent while activated carbon took out only 50% of the As.

Keywords:

AAS, Activated Carbon, Adsorption, Arsenic, Ferric Chloride, Ferrous Sulphate, Groundwater Contamination, Portland Cement.

CHAPTER:1

INTRODUCTION

1.1 General

Water bodies such as aquifers, rivers, ponds, lakes, streams, groundwater or oceans subjected with impurities (organic or in-organic), is referred to water pollution. Water pollution could either be direct or indirect, depends upon how the pollutants have been released: directly or indirectly. Discharging of pollutants without proper and adequate handling into the water bodies contributes to water pollution. Both plants and organisms, living in the water get affected water pollution. Nearly every case of water pollution brings damaging effect: not limited to any particular kind or masses but also to the natural biotic communities. Water, on the whole is termed polluted when it is vitiated with anthropogenic impurities or it couldn't be used to hold up for man's purpose, such as drinking, bathing, cleaning or there is a marked shift in the ability of water to support any constitutive biological community such as fish or any other kind of aquatic animal. Apart from the industrial, domestic or manufacturing natural dumping phenomenon such as earthquakes, volcanos, storms, algae blooms, etc. causes major changes in the ecologic status of water or water quality.

1.2 Origin of Arsenic

Arsenic is an important chemical element which is dispersed throughout the earth's crust. Arsenic is found in many ores and minerals and also as pure crystal element. Arsenic gets introduced into the water bodies through the dissolution of ores and minerals and its magnitude in groundwater in some regions get raised as a result of severe weathering from local mountain and rocks. Industrial discharge also contributes arsenic to water in their nearby spaces. Arsenic has a variety of use in different industries e.g. wood preservative, in alloying agents, etc.. Incineration of fossil fuels like coal, gasoline, oil, etc. significantly contribute arsenic in the environment via disperses atmospheric settlement. Inorganic As can be found in the environment in various different forms but their quantity in natural waters is quite high and thus their fraction in drinking water is the maximum. It commonly exists as [As(III)] or trivalent arsenic and [As(V)] or pentavalent arsenate. Organic arsenic species are rich in sea fare and they are less damaging for health and are periodically removed by our body. Drinking arsenic enriched water postures greater threat to public health than any other forms.

The emission of arsenic in work places like mining or chemical industries is quite significant. [British Geological Survey. Source and behaviour of arsenic in natural waters. Wallingford, Oxon OX10 8BB].

1.3 Consequences of Arsenic Exposure

The symptoms and marks that come up with arsenic exposure vary pointedly between persons, geographic areas and population groups. There is no general definition of the ailment caused by As which complicates its assessment for health problem. Likewise there is no particular method to categorize those cases of internal diseases that are caused due to the exposure from arsenic. The extent of arsenic absorption directly through human skin is very minor and thus regular water handling works such as bathing, laundry, washing, etc. does not pose pronounced risk. The long term exposure of arsenic leads to a series of changes: change in pigmentation followed by non-malignant alterations of skin like hyper and hypo keratosis. If the exposure of arsenic is for a very long time say 10-15 years, it results into a great malignancy like cancer of the lungs, kidney, urinary bladder, skin, etc. Exposure of arsenic through drinking water has caused abominable infection of blood vessels which transformed into gangrene in some of the Asian countries like China (earlier province of Taiwan) commonly known as the 'black foot disease'. On the other hand, studies directed in some other nations have revealed that arsenic exposure causes less harmful effect on the peripheral vascular system. As per some readings carried out by different organisations, drinking arsenic water has caused the death of 2-2.7 lakhs of people from cancer of different body parts in Bangladesh. [NRC, 1998; SMITH, et al, 2000].

1.4 Arsenic Measurement

The accurate measurement of arsenic level relevant to health issues require laboratory analysis, sophisticated and particularly expensive techniques, amenities as well as skilled staff which either is not available easily or cannot be afforded in various parts of the world.

Although use of field test kits can depict high intensities of arsenic but they cannot be used for lower concentrations, also their reliability is uncertain. [Arsenic: a deadly poison in drinking water- americanwaterfilter.com/arsenic.html]

1.5 Prevention and Controlling

The most counteractive and important part is self-prevention from further contact. The economy and trouble of lowering As in drinking water upturns as the targeted concentration lowers. Prevention varies with mitigation technologies, availability of low arsenic water sources, concentration of arsenic in the rootage water, quantity of water to be treated, etc.

Control of arsenic is further difficult where drinking water is picked up from sources such as hand pumps, tube wells and wells, mostly common in rural areas. Low arsenic water is required generally for cooking and drinking purposes. And water owing higher concentrations of arsenic can be used safely for dirty washing and bathing. To upsurge the exposure arsenic sources, painting of the hand pumps (e.g. green for safe and red for unsafe) could be an operational and low cost way, which should be supplemented with effective health instructions. Apart from these, alternative low arsenic sources like rain water should be stocked and processed surface water can be made useable and applicable in some conditions.

Simple practices for household purposes such as reverse osmosis have turned out to be sustainable in different situations. Use of chemical sterilisers, easily available in the market could be a useful option for household treatment. A few of these chemicals serve the combine purpose of arsenic removal and disinfection. Still there are no verified techniques for eliminating arsenic at water collection sites like hand-pumps, wells or tube wells. And the technology for arsenic elimination in channelized water stream is reasonably pricy and demands technical supervision. It is irrelevant in some of the urban areas of developing counties and most of the rural spaces.
(ARSENIC: A Deadly Poison in Drinking Water - miraculewater.com/Arsenic.htm)

1.6 Arsenic Elimination

In groundwater arsenic exists in either arsenate or arsenite forms.Various techniques of arsenic removal are being used in different parts of the world for a very long time. Some of them are: Gregor (2001); Gupta et. al. (1978), Huang et. al. (1984)] Adsorption [Elizalde et. al. (2001);, Coagulation; Ion-Exchange [Clifford et.al (1991)], Precipitation [Chow (1997), Harper et. al. (1992), Raman et. al (1992)], Oxidation and Reduction, Ultra filtration [Bellack (1971)].

These techniques have been implemented on different hybrid materials such as activated charcoal, Iron, zeolites, pyrites, etc. In the present work, Activated Carbon, Coarse Calcite and

Hardened Paste of Portland Cement (HPPC) have been used for preparing hybrid materials. Arsenic adsorption reactions are influenced by change in pH, concentration of the hybrid material, time period and rate of adsorption and presence of competing anions.

CHAPTER:2

LITERATURE REVIEW

2.1 Context

Natural dumping phenomenon such as earthquakes, volcanos, storms, algae blooms, etc. causes major changes in the ecologic status of water and water quality. Statistics exemplify the scale of problem that adulterated water like chemicals discharged from factories or washed down drains can cause **[**D. Mohan et al (2007)**]**. About half of the ocean pollution is due to the dumping of sewage and polluted water. Every single year, the world produces beyond 40, 00,000 lakh tons of industrial sludge**,** whose maximum proportion is dumped directly into oceans, rivers and other waterways. In India only, around 4, 00,000 factories take fresh water from streams and rivers and polluted waters are pumped back in their place. However, major improvements have been carried out in waste water treatment recently [C. Su et al (2001)]. Most common valence states of arsenic are As(V) and As(III). Arsenate (As(V)) is commonly found in aerobic surface water and Arsenite As(III) is more common in anaerobic ground waters. The presence of arsenic in groundwater is mainly due to mineral precipitation, leaking out of geological materials or dissolving of unstable arsenic ores, desorption- adsorption, chemical transformations and input from pesticides, fertilizers and geothermal sources. As(III) is the reduced form of inorganic arsenic, which is a extremely poisonous[Mandal et.al (1997)]. It is highly toxic, soluble and mobilized than inorganic arsenic (As-V). The disadvantageous presence of As in the environment is of great concern. Arsenic forms 0.0006% of the entire mass of the earth's crust. Consumption of adulterated water, whose arsenic concentration is above 0.05ppm, is detrimental for human health. In West Bengal, arsenic poisoning by drinking tube well water was first reported in the year 1980[Kundu et. al (2002)]. Long-term intake of arsenic adulterated water may cause pigmentation, hyperkeratosis on the palms and soles of the feet. Black foot disease, skin cancer, bone marrow depression, cardiovascular disorder and cirrhosis are instigated by long term exposure of arsenic. In view of the catastrophic effects within Asia due to As intake, Bangladesh is at the top tailed by West Bengal (India), Cambodia and Vietnam, where more than 15 crores people are at danger in West Bengal and Bangladesh alone. In all these areas, arsenic happens to be in deltaic soil deposits constituting shoal aquifers **[**J. Pattanayak et. al (2000)**].**

2.2 Arsenic contamination of groundwater in India

Over the past the natural anthropogenic presence of toxic arsenate or arsenite ions in groundwater has been acknowledged as a chief public health substance in different parts of the world. Substantial contamination of As has been ascertained in more than 40 different countries across the world including West Bengal, India and Bangladesh and their adjacent counties which shows its catastrophic exposure. Earlier the allowable contamination of As in drinking water was 50ppb [Safe Drinking Water, WHO, 1984]. Realising its carcinogenic effect on human health all across the globe and that the exposure is mainly through food and drinking water, WHO reviewed into the permissible levels and provided a guideline of 10ppb [Arsenic Contamination in Groundwater, WHO, 1993]. Duration and dosage of exposure are two crucial parameters of the severity of arsenic effect. It starts with change in pigmentation; hyperkeratosis and following to horrendous diseases like cancer of the skin, lungs, etc. In India, the unwellness due to arsenic consumption is mostly common in the rural areas where groundwater is used directly for drinking, bathing, cleaning and various other household works without its proper treatment. This is most likely due to the absence of services from the government [Chowdhury U.K., Biswas B.K., Chowdhary T. R. (2000)].

The water required for domestic supply in India (including West Bengal) is derived from rivers or canals. Deep tube well serves to be one of the most significant sources of groundwater, which are quite lesser in number in. Because of the small numbers of deep tube wells, the threat of arsenic intoxication in West Bengal is lesser in comparison to Bangladesh. According to a study performed by W.H.O it is estimated that approximately 5.2 crores people worldwide are drinking ground water whose arsenic level is above 10 ppb (or 0.01ppm). The government of both India and Bangladesh have allowed the contagion limit of arsenic at a marginally higher rate of 0.05ppm [I.S. 10500. 2012]. The World Health Organisation has categorised the pretentious areas of West Bengal under threat into three classes: Out of the nineteen districts of West Bengal, nine of them have been testified to have above 0.05 ppm of arsenic level. The total populace of those nine districts is above 3.4 crores and the number of people using arsenic rich water coarsely goes above 10 lakhs (above 0.05 ppm). That amount rises to 13 lakhs when the concentration level is set above 0.01 ppm [Chowdhury U.K., Biswas B.K., Chowdhary T. R. (2000)].

More than 13 districts of Bihar have been reported to have As contamination level above the Indian standards. The reason being all these districts are located nearby large rivers like *The Ganga and The Gandak* [Biharprabha News, 25 September 2013].

Depending upon the contamination level of arsenic in groundwater calculated in the 19 districts of West Bengal, they are categorised in three different classes: severely affected, mildly affected and arsenic safe.

Sl. No	Districts	Arsenic Level	Class
1.	Nadia, North-24Parganas, Malda, Murshidabad, South-24-Parganas, Howrah, Hoogly, Bardhaman, and Kolkata	Above 300 ppb	Severe
2.	Koch Bihar, North Dinajpur, Darjiling, South Dinajpur and Jalpaiguri	In between 50 and 10 ppb	Mild
3.	East and West Bankura, Birbhum, Medinipur and Purulia	Below 10 ppb	Safe

[School of Environmental Studies, Jadavpur University.2006)]

Table 1: Categorisation of different districts of West Bengal on arsenic severity

CHAPTER:3

METHODOLOGY

Arsenic in groundwater is found out in two different forms: Arsenate (As(V)) and arsenite (As(III)). Arsenite in comparison is more harmful than arsenate. Different methodologies are there for their treatment. In the present study coagulation and adsorption techniques are applied for eliminating arsenic. A few hybrid materials namely: Activated Charcoal with Ferric Chloride, Hardened Paste of Portland Cement, Coarse Calcite with Hydrous Ferric Sulphate were used efficiently to eliminate arsenic from the prepared sample.

3.1 Activated Carbon

Activated charcoal or activated carbon or simply charcoal is a typical form of carbon which is prepared by burning of coal or organic matter like animal bones or coconut shells in controlled conditions. Due to this action millions of tiny pores get cased in between the carbon atoms and it also increases the surface area (per unit mass) of the charcoal, which lies in the range from 500 to 1600 m^2 per gram. The increased surface area of the activated charcoal makes it suitable for *adsorption*, process by which impureness in substances such as liquid or gases are removed. Impure molecules get stick to inside to the internal pores of carbon through chemisorption or electrostatic attraction.

3.1.1 METHODOLOGY TO USE ACTIVATED CARBON AS AN ADSORBENT (Fierro V. et al. (2008))

I. A sample of 0.05ppm (500mL) Arsenic solution was prepared

II. Activated carbon along with Ferric Chloride was used as adsorbent.

III. 22g of activates carbon was passed through 400 mesh size, out of which approximately 4 to 4.5g got retained and rest passed.

IV. 650 ml of 0.05M $FeCl_3$ was prepared in the acidic medium.

V. Approximately 17-17.5g of AC, which retained on the mesh, was boiled in 1M HNO_3 for 2 hours at 100^oC.

VI. Subsequently to dry up the charcoal the above solution of activated carbon (AC) with HNO_3 was kept in the oven for a complete day.

VII. The dried mass of activated carbon weighed 14.5g.

VIII. Four samples were prepared; for each sample 3.5g of AC was added to 150mL of 0.05M $FeCl_3$.

IX. Forced Hydrolysis was next carried out on each of the four samples at 100^oC for 1h, 3h, 6h and 24h respectively.

X. Afterwards the pH(s) of all the samples were made neutral by adding HCl and NaOH.

XI. These samples were dried overnight in the hot air oven at 80^oC.

XII. Now the activated carbon is ready for the implementation.

XIII. From each sample, 3g of AC was added per 100mL of 0.05ppm As solution.

XIV. Potassium Iodide (10%) and HCl (10%) (by volume) were also added to each of the samples.

XV. Each sample was kept on the mechanical shaker for 45 minutes and 40^oC and stirred at 240rpm.

XVI. The solution was passed through 6μm filter paper.

XVII. For the quantification and efficiency of arsenic removal, the filtered samples were analysed by using AAnalyst 200 Atomic Absorption Spectrometer at λ = 193.7nm, silt = 0.7, argon flow = 50mL/m and pump velocity = 120 rpm.

XVIII. For each of the four samples, two readings were taken and the average of those two was reported as the final concentration.

3.2 Coarse Calcite with Hydrous Ferric Sulphate

The removal of impurities by using coagulants is called coagulation. Coagulation is a process in which the colloids get altered and consequently they get nearer to each other and cling upon themselves to form big floc structure. The objective of coagulation is to pool the small particles of contaminants such as bacteria into large flocs, either as suspended particles or precipitates. These floc molecules are then conditioned so that they could move out in the subsequent process.

3.2.1 METHODOLOGY TO USE COARSE CALCITE FOR THE REMOVAL OF ARSENIC (Song S. et. al. (2004))

I. A sample of 5ppm (200mL x 5) Arsenic solution was prepared.

II. Hydrous Ferric Sulphate [$Fe_2(SO_4)_3.5H_2O$] and coarse calcite [$CaCO_3$] were used as coagulant.

III. Calcite was taken and crushed. It was sieved to a size (less than 38µm) by 400 mesh size.

IV. Calcite at (0, 2, 5, 7.5 and 10 g/L) density was added to the prepared 200 mL 5ppm As sample.

V. Ferric Sulphate [$Fe_2(SO_4)_3.5H_2O$] as added to each at 100mg/L.

VI. Sample solutions were stirred for 0.5h over the magnetic stirrer at 150 rpm and later on passed through 2.5µm filter paper.

VII. pH of the solution was adjusted in the range (5-8) by adding NaOH and HCl.

VIII. At 240rpm and 40˚C, the solution was kept agitated for 0.5h.

IX. It is filtered with Whattman Filter paper no. 41 i.e. (0.22 µm) Millipore white GSWP membrane.

X. Filtered sample was divided in 5 sample bottles, each containing 30 mL of the sample. To check the effect of pH, their pH(s) were varied from 4-12.

XI. For each pH, arsenic contamination was measured by using AAnalyst 200 Atomic Absorption Spectrometer (λ = 193.7nm, silt = 0.7, argon flow = 50mL/m and pump velocity = 120 rpm) by taking 15 mL at a time for analysis, the average of two values were reported as Arsenic level.

3.3 Hardened Paste of ordinary Portland Cement (HPPC)

3.3.1 METHODOLOGY TO USE HPPC AS AN ADSORBENT (Kundu S. et. al. (2004))

I. A sample of 0.2ppm Arsenic solution was prepared by using Merck's standard solution.

II. About 0.50 kg of Ordinary Portland Cement (43 Grade) was taken in a container. A slurry was prepared keeping water-cement ratio of 0.45.

III. The pH of the slurry was around 9. For the next 72 hours it was kept undisturbed for drying/hardening.

IV. After thorough air drying, the hardened pieces of cement were broken into small granules. Next, broken cement particles were dipped inside water for 96 h and later on hammered to obtain finer particles. These particles were dried in oven for 72 hours at 100–110 ˚C.

V. The prepared adsorbent was taken in sample bottles of 150 mL capacity holding 100 mL of 0.2ppm arsenate solution.

VI. The quantity of adsorbent taken was altered in the range of 2-25g/L. For thorough mixing, sample bottles were kept on the mechanical shaker and rotated at a speed of 150 rpm for 8h.

VII. The above sample was filtered with 0.2μm filter paper. And the filtered sample was sent out for quantification.

VIII. Arsenic contamination was measured by using AAnalyst *200* Atomic Absorption Spectrometer (λ = 193.7nm, silt = 0.7, argon flow = 50mL/m and pump velocity = 120 rpm) and reported as the average of two values for same bottle.

IX. To study the effect of pH, concentration of the adsorbate and adsorption period, the methodology was varied accordingly.

CHAPTER:4

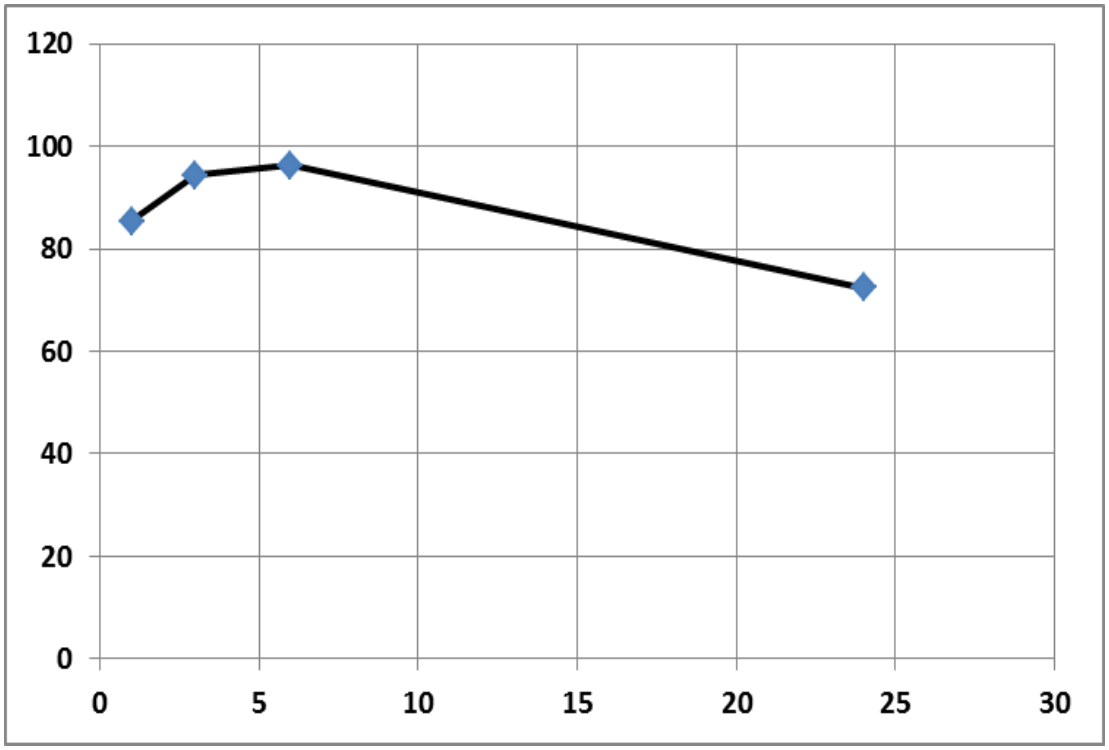
RESULTS AND DISCUSSION

4.1 Activated Carbon (Charcoal)

4.1.1 Efficiency of As removal by varying Hydrolysis period

Forced Hydrolysis period(in h)	Iron content in activated carbon (% by wt.)	Initial concentration (in ppb)	Final concentration (in ppb)	Percentage Removal
1	1.5	50	7.351	85.30
3	2.0	50	2.815	94.37
6	2.2	50	1.189	96.22
24	9.4	50	13.835	72.33

Table 2: Arsenic Removal by Activated Carbon



Graph 1: Arsenic Removal by Activated Carbon

We can infer that Activate Carbon (AC) with iron deposition ranges from 1.5% to 9.4% (by weight). This is due to forced hydrolysis with $FeCl_3$. As the hydrolysis period increases-the deposition of iron increases and so increases the efficiency of As removal. But if hydrolysis period is very long, like 24h, though the deposition of iron increases but efficiency decreases. This may be due to the presence of iron oxide (or hydroxide): which once get hydrated hinders & even prevents diffusion of arsenic.

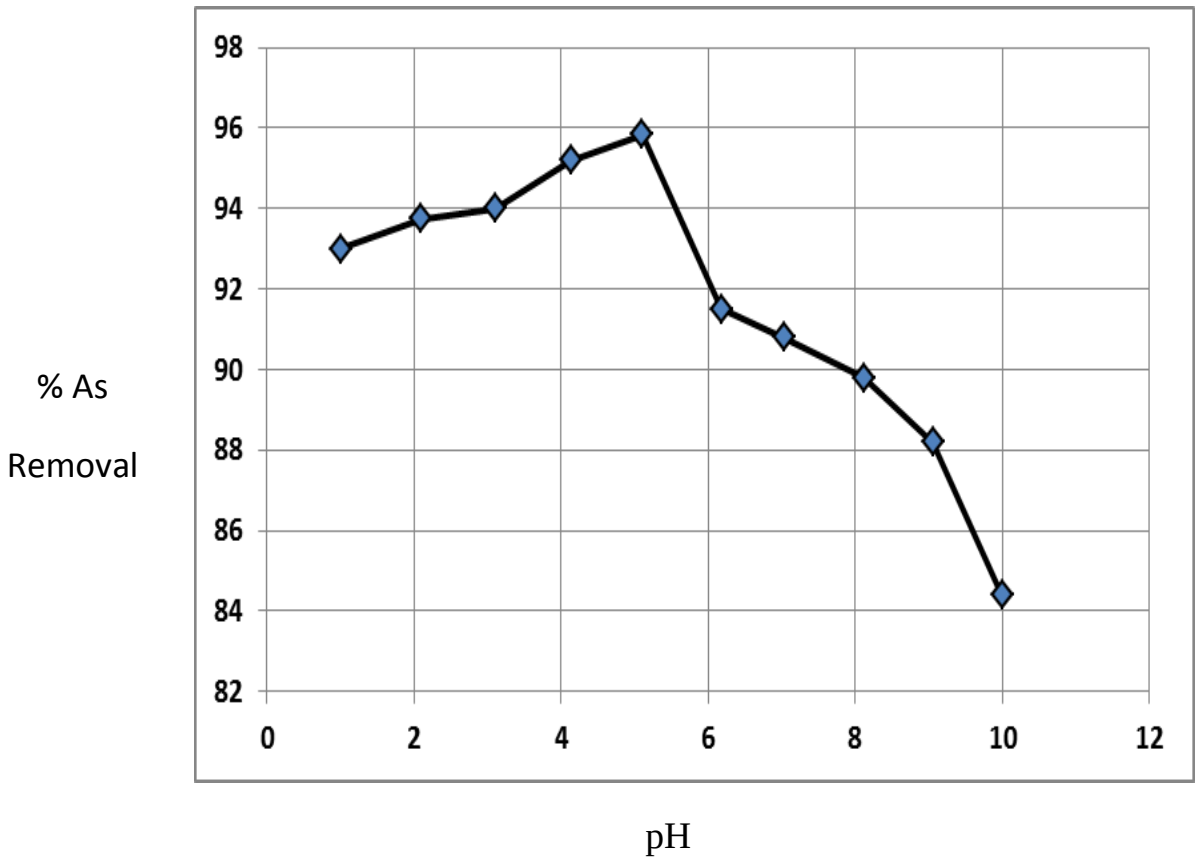
4.2 Hardened Paste of Portland Cement (HPPC)

4.2.1 Efficiency of As removal by varying pH

- HPPC Concentration: $15gL^{-1}$
- Time of adsorption: 8 hours

pH of the sample	Initial concentration (in ppm)	Final concentration (in ppm)	Percentage Removal
1.00	0.2	0.014	93.00
2.10	0.2	0.013	93.75
3.10	0.2	0.012	94.00
4.13	0.2	0.010	95.20
5.10	0.2	0.008	95.84
6.18	0.2	0.017	91.50
7.03	0.2	0.018	90.80
8.12	0.2	0.021	89.80
9.06	0.2	0.024	88.20
10.00	0.2	0.023	84.40

Table 3: As removal using HPPC by varying pH



Graph 2: As removal using HPPC by varying pH

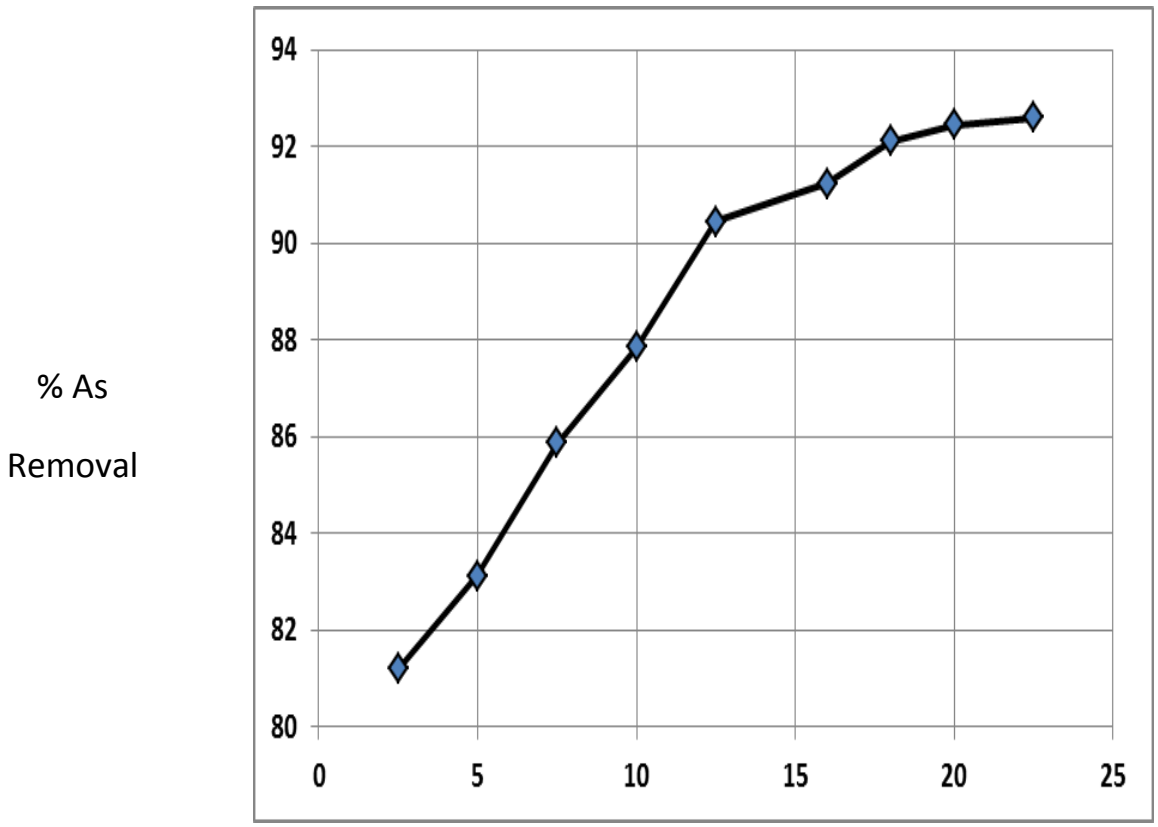
pH of the solution influences the chemical property of both adsorbate and adsorbent. In acidic media, the reactions are quick and agile and so the efficiency is quite high. In the basic medium, the adsorption decreases sharply, this is due to the struggle between arsenate and the interfering OH^- ions for the adsorption positions (chiefly Fe^{3+}).

4.2.2 Efficiency of As removal by varying concentration

- pH level: 5.0
- Time of shaking : 8 hours

HPPC Concentration (in gL^{-1})	**Initial concentration (in ppm)**	**Final concentration (in ppm)**	**Percentage Removal (approx.)**
2.5	0.2	0.038	81.20
5.0	0.2	0.034	83.13
7.5	0.2	0.028	85.87
10.0	0.2	0.024	87.84
12.5	0.2	0.019	90.44
16.0	0.2	0.018	91.23
18.0	0.2	0.016	92.10
20.0	0.2	0.015	92.45
22.5	0.2	0.015	92.60

Table 4: As removal using HPPC by varying its concentration



Graph 3: As removal using HPPC by varying its concentration

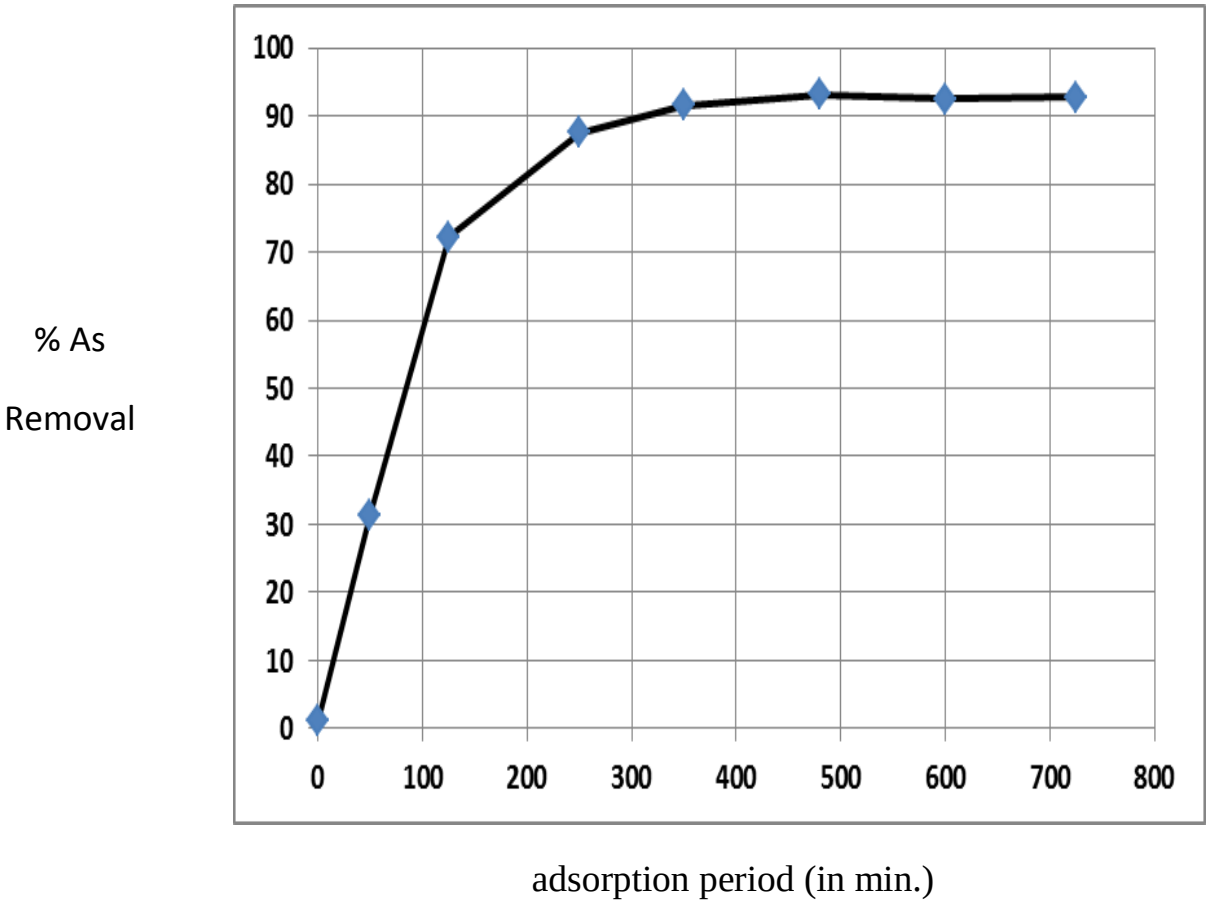
As the concentration of the adsorbate, HPPC was increased keeping other parameters such as pH and adsorption period constant, the efficiency of arsenic removal goes on increasing. And at higher concentrations, the removal % is almost similar.

4.2.3 Efficiency of As removal by varying adsorption time

- HPPC concentration: $15gL^{-1}$
- pH level: 5.0

Adsorption Time (in min)	Initial conc. of the sample (in ppm)	Final conc. of the sample (in ppm)	Percentage removal (approx.)
0	0.2	0.198	1.20
50	0.2	0.137	31.40
125	0.2	0.056	72.20
250	0.2	0.025	87.60
350	0.2	0.017	91.60
480	0.2	0.014	93.18
600	0.2	0.015	92.52
725	0.2	0.014	92.80

Table 5: As removal using HPPC by varying adsorption time



Graph 4: As removal using HPPC by varying adsorption time

Keeping the pH and concentration of the adsorbate constant, the action period was increased. In the very beginning, the % removal of arsenic goes on increasing but afterwards the removal efficiency appeared to remain constant over the time being. This shows after the equilibrium has been achieved, adsorption did not change much.

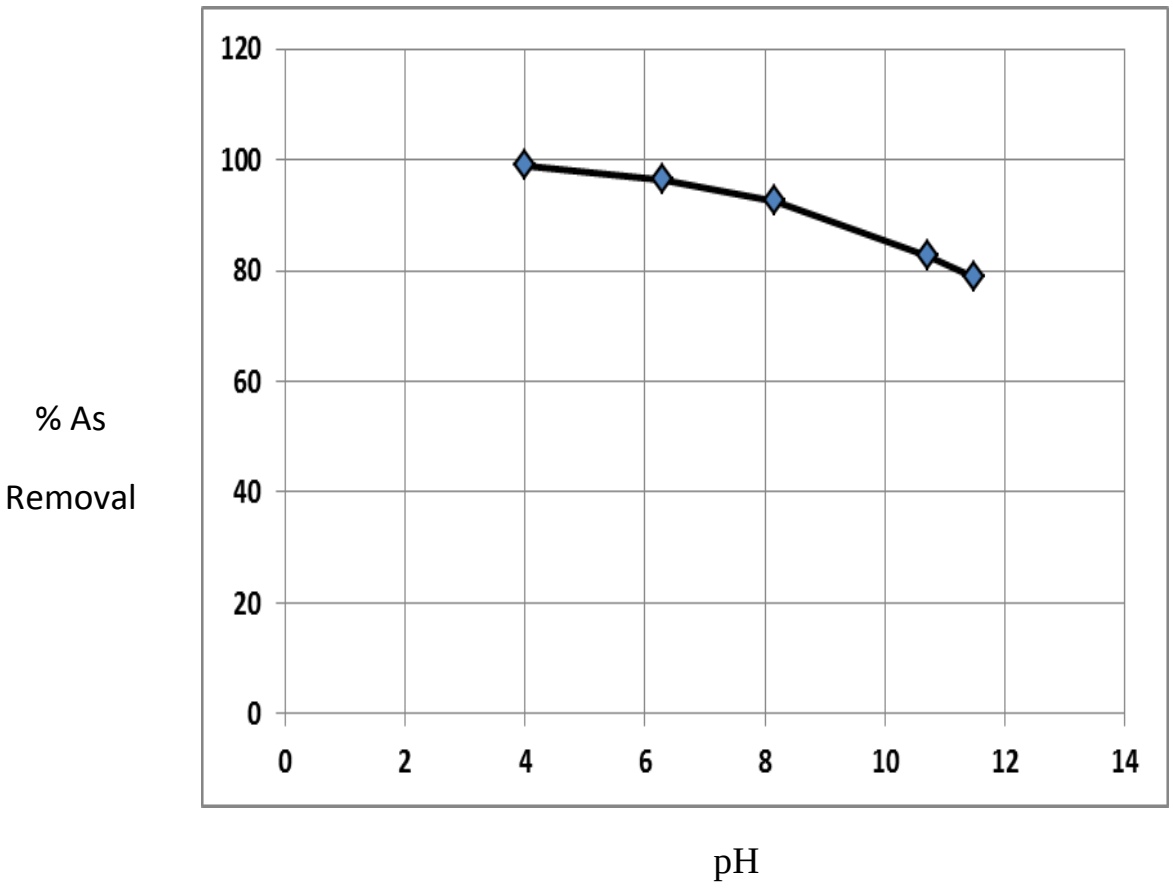
4.3 Coarse Calcite and Hydrous Ferric Sulphate

4.3.1 Efficiency of As removal by varying pH

- Calcite Concentration: 5g/L
- Time: 30minutes

pH of the sample	**Initial concentration (in ppm)**	**Final concentration (in ppm)**	**Percentage Removal**
4.00	D 5	0.051	99.00
6.30	5	0.175	96.50
8.16	5	0.375	92.50
10.72	5	0.871	82.60
11.49	5	1.061	78.80

Table 6: As removal using Coarse Calcite by varying pH



Graph 5: As removal using Coarse Calcite by varying pH

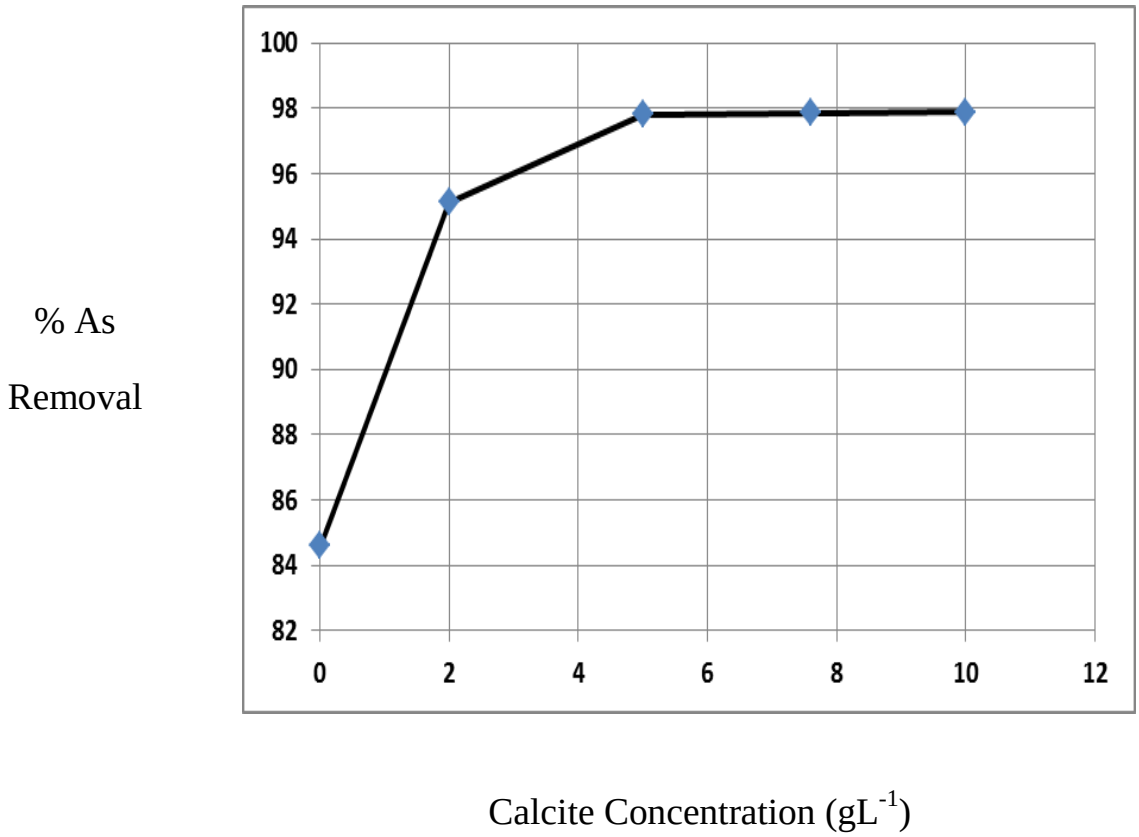
pH of the solution affects the kinetics and rate of adsorption. The above graph suggests that in the acidic range, arsenic removal (~99%) would be very high, while in the alkaline region, the arsenic removal curve has undergone declination with increase in pH. This shows that coagulation is very effective in removing arsenic from high arsenic water in acidic media.

4.3.2 Efficiency of As removal by varying conc. of calcite

- pH level: 6.30
- time: 30 minutes

Calcite (in g/L)	**Initial concentration (in ppm)**	**Final concentration (in ppm)**	**Percentage Removal**
0.0	5	0.771	84.60
2.0	5	0.245	95.12
5.0	5	0.111	97.80
7.6	5	0.107	97.86
10.0	5	0.106	97.88

Table 7: As removal using Coarse Calcite by varying calcite concentration

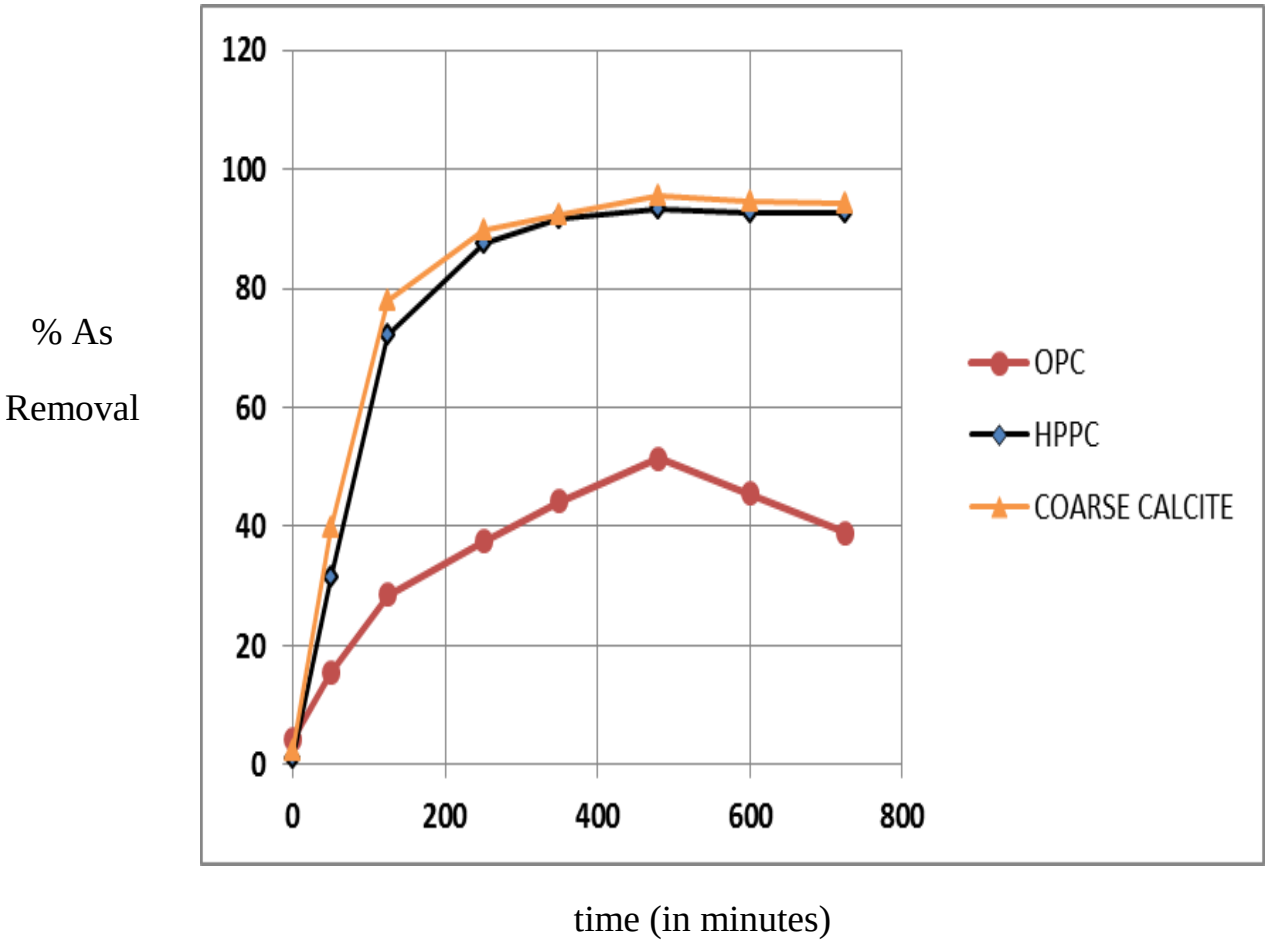


Graph 6: As removal using Coarse Calcite by varying calcite concentration

The pH of the sample was made about neutral and initial concentration of the calcite was taken as cypher. Consecutively on increasing the concentration the elimination rate gained a speedy rate and the efficiency of arsenic removal was found almost similar for concentration of 5.0, 7.6 and 10.0 g/L.

4.4 Comparability of Hybrid Materials

To compare the removal efficiencies of these hybrid materials, a sample of 0.2 ppm was prepared and the results obtained are as follow:



Graph 7: Comparison of the efficiencies of different hybrid materials

CHAPTER:5

CONCLUSION

(A) HARDENED PASTE OF PORTLAND CEMENT:

HPPC indicated to be an efficient adsorbent for arsenic removal. In perspective of the present study the maximum elimination of arsenic was found to be 95 percent. The maximum removal efficiency was attained in the range of 4–5 pH(s), but the effectiveness drops with increase in pH. Either this is due to the diffusing behaviour of meddling anions, present in solution or favoured binding of arsenate with the metal ion. As the concentration of the adsorbate i.e. HPPC was increased, the removal efficiency increased rapidly. Thus, concentration of the adsorbate is directly proportional to removal efficiency. The absorption period is quite substantial. With increase in the adsorption time, the elimination rate goes on increasing. But when the equilibrium is achieved, with further gain in time there is not remarkable change in the removal efficiency.

(B) ACTIVATED CARBON:

The addition of ferric chloride with activated carbon suffices the elimination of arsenic. Forced hydrolysis increases the iron content of activated charcoal. In the present study, the deposition of iron content was obtained in the range of 1.5 to 9.4 percent by weight. Concentration of deposited iron upsurges with hydrolysis period. It was pointed out that higher the concentration of iron content within the AC- higher is the elimination of arsenic. But for the iron doped activated carbon, whose hydrolysis period was 24h, arsenic deposition was very low. This phenomenon is possibly due to the presence of cluster of iron hydroxides nanoparticles, which once get hydrated hinders and even prevents diffusion of (As(V)) ions on activated carbon grains.

(C) COARSE CALCITE:

Coagulation/filtration technique for the removal of arsenic showed vivid results. The elimination of arsenic was almost 100 percent for a 5ppm As solution, though the efficiency curve declined with increase in the pH value which shows removal efficiency is related reciprocally to the pH of the solution. With increase in the concentration of calcite, the efficiency curve rises and it shows that efficiency of the elimination of arsenic varies directly with the concentration.

CHAPTER:7

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